Motivators for adoption of photovoltaic systems at grid parity: A case study from Southern Germany

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a b s t r a c t

In some countries, photovoltaic (PV) technology is at a stage of development at which it can compete with conventional electricity sources in terms of electricity generation costs, i.e., grid parity. A case in point is Germany, where the PV market has reached a mature stage, the policy support has scaled down and the diffusion rate of PV systems has declined. This development raises a fundamental question: what are the motives to adopt PV systems at grid parity? The point of departure for the relevant literature has been on the impact of policy support, adopters and, recently, local solar companies. However, less attention has been paid to the motivators for adoption at grid parity. This paper presents an in depth analysis of the diffusion of PV systems, explaining the impact of policy measures, adopters and system suppliers. Anchored in an extensive and exploratory case study in Germany, we provide a context specific explanation to the motivations to adopt PV systems at grid parity.

Contents

1. Introduction

Concerns about climate change and limited resources of fossil fuels have prompted governments to support the emergence and diffusion of renewable energy systems. The European Union (EU) has set targets of 20% share of renewable energies in overall energy consumption by 2020 [16]. One of the renewable energy sources that is expected to pave the way for achieving this goal is the solar photovoltaic (PV) systems. If all specific boundary conditions are met (e.g., shifting energy policies from conventional electricity generation to renewable energies and the reduction of the levelized cost of PV electricity), it is estimated that solar PV systems will supply up to 12% of the EU electricity demand by 2020 [17]. Germany is in the forefront of solar PV deployment, exhibiting a steady growth until 2011 that made the Germany the most developed PV market in the world, with 24,678 MW of installed capacity [18]. According to some studies (e.g. [39,49,56,10]), solar PV energy in Germany had already achieved grid parity by 2012, i.e., solar PV energy can directly compete with conventional electricity sources in terms of the levelized cost of electricity generation.

The German feed in tariff scheme is widely accepted as the strongest driver for the diffusion of PV since 2000 [14]. This scheme ensures that solar PV adopters (when they supply electricity to a grid) get paid by fixed feed in tariffs over 20 years,. However, the feed in tariff for solar PV systems has decreased more rapidly than that for any of the other renewable energy technologies [61]. Although solar PV systems in Germany are often assumed to be at grid parity, the PV market has recently faced uncertainties related to the cuts in the feed in tariff. The reduction and the ultimate end of the policy support pose fundamental questions about the diffusion of solar PV systems: how will they be deployed when the feed in tariff diminishes? What are the motivators to adopt PV systems at grid parity? In the literature, the diffusion of PV technology has been studied regarding the aspects of, first, policy support, including feed in tariffs [30,32,66], second, adopters' influence [9,43,50,66] and, recently and finally, the role of local solar companies [15,20]. Although some studies have conducted economic analysis of the stage in the deployment of solar PV when grid parity is approaching (e.g. [25,56]), less has been discussed about the adopters' motivations.

Based on an extensive and exploratory case study, the aim of this paper is to extend the debate by providing multiple wealth of empirical details in a context limited knowledge (suggested by [21,64]). We focus on the diffusion of solar photovoltaic systems and analyze the motivations to adopt PV systems. We frame these motivations associating with the roles of the policy measures, adopters and local solar companies. The case study is based on Hartmann Energietechnik GmbH (HET) in Southern Germany, a leading local solar company that has been engaged in the diffusion of solar PV systems in the region since the early 1990s. Apart from this introduction, this paper is structured as follows. Section 2 develops the analytical framework to be used for interpreting the data. Section 3 explains the research methodology. Section 4 introduces the case study. Section 5 analyses the results of the empirical research and discusses the key motivators for the diffusion process. Finally, Section 6 presents the conclusions and future lines of research.

2. Analytical framework

Diffusion of innovations is a multidimensional process [see e.g. 57,34]. The availability of a new technology or innovation, such as solar PV technology, does not necessarily motivate its adoption by individuals. The perceived attributes of an innovation, which is contingent upon the adopters, explain 49 87% of the variance on the different diffusion rates of different innovations [54,59]. These attributes are relative advantage, compatibility, complexity, trialability, and observability. *Relative advantage* refers to the degree to which an innovation is perceived to be better than the incumbent idea, technology, or practice and is usually expressed as economic profitability. However, non economic factors (e.g., quality, satisfaction, environmental awareness and social prestige) are also important. This is also the case of the PV diffusion (e.g. [32,45,48]). *Compatibility* is the degree to which an innovation is perceived as being consistent with the existing values (e.g., sociocultural values and beliefs), past experiences (e.g., previously introduced ideas), and the needs of potential adopters. Several studies points to a direct relationship between the compatibility of an innovation and its adoption in the case of PV technology [43,55]. *Complexity* is the degree to which an innovation is perceived as being relatively difficult to understand and use. Generally, there is an inverse relationship between the perceived complexity of an innovation and its adoption rate [33,38,63], as was experienced in the diffusion of solar PV systems [1,32]. *Trialability* is the degree with which an innovation may be experimented on a limited basis. Innovations with high trialability often have a higher diffusion rate [42,54], although some other studies [38,63] indicate an absence of a relationship between trialability and the adoption of innovations in the energy sector. Finally, *observability* is the degree to which the results of an innovation are visible to others. According to Tidd [59], the rate of adoption of an innovation increases when it is easier to see the benefits of this innovation.

As Rogers [54] argues, the decisions regarding adopting innovations can be categorized as optional (where the adopting individual has almost complete responsibility for the decision), collective (where the individual has a say in the decision) and authority (where the adopting individual has no influence in the decision). Because all of these types of decisions center on individuals, there has been some criticism that they do not provide sufficient emphasis on structure, context, or collective action [60]. However, the diffusion process may involve a mix of all of these decision making types, depending on the type of technology, regulations and adopters, as is the case of the renewable energy technologies in different countries [8,51].

Innovation diffusion requires communication channels by which messages are transmitted from one individual to another [54]. Interpersonal communications (including non verbal observations) and mass media channels (television and internet) are important influences on the diffusion rate of the innovations in a social system [41,54]. Communication between adopters and the observability of the adoptions can induce peer effects, whereby the decision of potential adopters may be influenced by the previous adopters [9]. Recent literature has paid much attention to how peer effects influence the diffusion of PV technology [46,53].

In addition, the variables determining the rates of adoption are influenced by a social system, which is a set of interrelated units that are engaged in joint problem solving to accomplish a goal [54]. The members of a social system may be individuals, informal groups, organizations and/or subsystems. Potential adopters can be influenced to adopt an innovation by the pressure of the social system generated via adopters, public policies, shareholders and organizations [4,22]. Some recent research have identified the effects of network externalities as being significantly important for the diffusion rate of innovations [7,23].

Finally, the diffusion process is boosted by the presence of a change agent, who is an individual that influences the decisions of potential adopters in a direction deemed desirable by a change agency. Rogers [54] identifies the seven roles of change agents as developing a need for change, establishing an information exchange relationship, diagnosing problems, creating an intent to change in the adopter, translating an intent into action, stabilizing adoption (e.g., preventing discontinuance) and achieving a terminal relationship. The PV industry in Germany [13] and wood fuelled heating systems in Austria [40] indicate that change agents could vary, depending on the context and innovations: local companies, architects, foresters, non profit organizations and banks.

2.1. Policy measures

An important motivator that can induce the diffusion of envir onmental innovations, such as solar PV technology, is government policy [52,12]. Policy might have the capacity to create expectations for an environmental innovation and provide clear signals to potential adopters and industrial actors regarding the future attrac tiveness of it. In this context, policy makers can foster specific regulations to guide suppliers and adopters to choose an innovation or a specific design, which in return may increase the economical relative advantage of the innovation. Until 2012 in Germany, policy makers provided clear signals regarding the growth potential of solar PV systems through the implementation of feed in tariff [15,27,30]. Such tariffs influence the perceived economic relative advantage of solar PV and, therefore, the diffusion [32].

Beise [5] also argues that the successful diffusion of PV technology in Germany and Japan was based on government policies. An illustrative case is that the policy makers in Germany supported the market formation with the implementation of the 1000 roofs program in the early 1990s and the 100,000 roofs program in 1999, which led to the formation of the small scale home owner systems market and therefore promoted the diffu sion of solar PV systems [14]. In this case, policy makers also influenced the agents (manufacturers and local solar companies) to play an important role in increasing the relative advantage of solar PV technology.

Finally, as a matter of social acceptance, policy makers may organize information and support meetings to reduce the per ceived complexity of an innovation and to ensure legitimacy, thereby increasing the rate of adoption of the innovation [32]. For instance, in the early 2000s, the support of two members of the German Parliament (CDU, the liberal conservative political party, and CSU, the conservative political party) made the revision of feed in tariff possible, which accelerated the diffusion of solar PV systems in Germany [30].

2.2. Adopters

The role of adopters in the diffusion process has been studied from different perspectives, such as the supply side, with regards to how suppliers can learn from adopters to develop and improve their products [26], and the early adopters, regarding the motivat ing role of these consumers on the diffusion processes [54]. For a mature innovation, such as solar PV technology, the literature focuses on two research areas: demand side factors, in the sense of which characteristics of adopters influence their decision to accept an innovation, and peer effects, in terms of how adopters influence each other in a social system.

Relevant studies have identified individual characteristics that distinguish early adopters from late adopters can influence the perception of all innovation attributes. In this context, the compat ibility of an innovation with previously introduced ideas and social norms can either speed up the adoption process or retard its rate of adoption, whereas the desire to gain social status of potential adopters may be one of the reasons to adopt an innovation [54,58]. In the case of PV systems, the characteristics of adopters that have a higher level of influence on the diffusion of PV systems can be grouped as personality variables, economic status and socio geographic context. Related to the first group of personality variables, the consumers perceive a PV system as being important in satisfying their needs and have cognitive capacity, experience and knowledge to overcome the complexities of the decision. In this context, early adopters usually have higher than average general environmental problem awareness, and they are more aware of the relative advantages of PV systems [32]. Other factors that can play a relevant role are the desire to be independent from the electricity supplier, familiarity, religion and education [2,32,43,50]. Related to the other groups, literature asserts that the diffusion of PV systems is accelerated with the increase of sunshine duration and the housing investment of per capita household income [66].

Regarding peer effects, early adopters of an innovation can exchange the information of relative advantage with the potential adopters by expanding the knowledge about the degree to which an innovation is better than the existing practices [54]. New adopters are influenced in part by what they see and hear from their peers. Previous adoptions in the same localized area play a role in the decision of a household to adopt [9]. Adopters of PV systems may act as “advisors” for their peers and neighbors with respect to the installation of a PV system and the administrative procedures involved, which increases the observability and trial ability of the innovation and stimulate further diffusion [32]. Peer effects can be fostered if highly motivated adopters formalize social networks to circulate information. These networks may increase the involvement of potential adopters who were initially not interested or aware of the possibility to install a PV system [32]. Dewald and Truffer [15] illustrated an example in Germany, where some PV adopters and suppliers participated in the initia tion of the green movement, with a strong emphasis in protesting against the use of nuclear energy.

2.3. Local solar companies

Local solar companies promote either a package of innovations (elements of technology that are perceived as being interrelated) or each new idea separately. Christensen [11] explains the impor tance of compatibility for the role of suppliers in terms of “disruptive innovations” as two aspects. First, the pace of diffusion can be different from the progress offered by the technology. Second, a disruptive innovation should fit the needs of current potential adopters. In this context, local solar companies may seek to generate needs among potential adopters, but this must be performed carefully. If the campaign is based only on the needs of the change agents, rather than those of the adopters, it may result in fail [54].

The communication between local companies and potential adopters can primarily improve the relative advantage of an innovation as perceived by potential adopters. This communica tion is more critical in the cases of environmental innovations, such as solar PV technology, because the relative advantage of such innovations can occur at some time in the future. As some environmental innovations require a high level of knowledge regarding operation and financing, effective communication or sharing of a similar backgrounds between suppliers and adopters is mandatory [15]. In the case of the diffusion of PV technology in Germany in the 2000s, [10] the architects, who acted as system suppliers, were committed to provide information about the technology, financing and funding to potential adopters in the small scale (1 10 kW_p) PV market.

Another advantage that is derived from communication between local solar companies and other actors is the possibility to generate networks that influence the diffusion of innovations. Poor cooperation in networks may fail to enforce the diffusion of innovations, while tight networks cause lock in effects [6]. Well established networks take an active role in market forma tion, knowledge generation, legitimation and creating positive external economies. For example, in the 1970s, the foundations of the German Society for Solar Energy and the German Solar Energy Industries Association primarily created positive external economies for the later stages of the diffusion of PV systems in Germany [31].

3. Methodology

Because the research questions and the area of investigation are relatively novel, an extensive and exploratory case study research is chosen as a methodology [64]. The research design has an insider outsider team research approach [3] with one of the researchers spending three months (winter 2012 2013) at a local solar company in Southern Germany (Hartmann Energie technik GmbH), which gave us unlimited access to study the interaction of the firm with adopters. The other two authors acted as outsiders to enhance the capturing of multiple perspectives. The main data source was collected through direct (face to face) interviews with adopters and employees of the firm. The duration of interviews varied between 10 min and 1 h. All interviews were semi structured, involving open ended questions using an inter view guide, with freedom to modify and re order questions and add new questions based upon the respondent's act. All of the interviews were translated and analyzed in order to capture the main motives of PV adopters.

The purpose of interviewing both adopters (demand side) and employees in the firm (supply side) was to obtain a deeper understanding of the context of diffusion of solar PV technology. The respondents from the demand side included the adopters that bought PV systems during 2012, the year that the German feed in tariff was rapidly reduced. In total, nine PV adopters were inter viewed of a total of 34 PV adopters that installed PV systems from the company in 2012. All of the respondents were located in Tuebingen, mainly in the area of Rottenburg am Neckar. The respondents from the supply side included five technical and marketing staff members of the local solar company, who interact with adopters of both PV and other alternative renewable tech nologies provided by the firm (solar thermal energy and biomass).

The interview data were triangulated with other data from four additional interviews with the directors of four partner firms of the regional PV association (Solar Partner e.V), observations made in the firm, meeting notes from the 2 day long annual meeting of Solar Partner e.V, and communications between adopters and the firm. Finally, all of these sources of information were complemen ted with secondary information collected from different internal reports of the firm, newspaper articles and website news. Special attention was paid to the PV feed in tariff history. The gathered data and information allowed us to identify and analyze the adopters' motivations associated with the roles of policy makers, adopters and a local solar company on the diffusion of PV when feed in tariff diminished in 2012.

4. The context of the case

We put the case study into the local context of PV diffusion in 2012. As background information, we explain the achievement of grid parity and the local solar company. The aim of this section is not to provide a comprehensive and historical description of the diffusion of PV in Germany, which has already been discussed in the literature from the policy and institutional perspectives [30,31] and the market formation perspective [14,15].

4.1. Grid parity

The technological development regarding the efficiency of the different types of solar cells is constantly improving [47]. A typical commercial solar cell has a ratio of electric generation to the sunlight striking the cell of approximately 20%. Moreover, from an economic perspective, the PV production cost has been continu ously decreasing. As a result of these developments, the perceived relative advantage of PV systems has been improved. Particularly in Germany, PV systems are assumed to be at grid parity, i.e., the price of solar PV electricity can compete with the price of conventional electricity sources [39,49,56,10].

The perceived economic relative advantage of PV systems is commonly explained in terms of the levelized cost of electricity (LCOE), €/kWh, a calculation of the cost of electricity generation that is based on different variables, such as the initial capital, solar radiation, costs of continuous operation, service life time and costs of maintenance. When the LCOE of solar PV electricity reaches to a level that is below the price of purchasing electricity from the grid, it means that solar PV is at grid parity in the corresponding country. The comparison of the LCOE of a PV system and the average electricity price in Germany indicates that since the beginning of 2012 the LCOE of a PV system was lower than electricity retail price (Fig. 1). By the end of 2012, the LCOE of a typical PV system in Germany was between 0.12 and 0.21€/kWh, whereas the electricity retail price was approximately 0.26€/kWh. This fact represents a rapid improvement in solar PV systems in comparison to May 2010, when the LCOE of a typical PV system in Germany was between 0.20 and 0.34€/kWh, while the electricity price was approximately 0.23€/kWh. As a consequence of this decrease of the PV LCOE and the increase of the electricity prices in Germany, the government has been gradually reducing the feed in tariff.

The adoption rate experienced some boom and bust cycles in recent years (see Fig. 2). The number of installations has notably

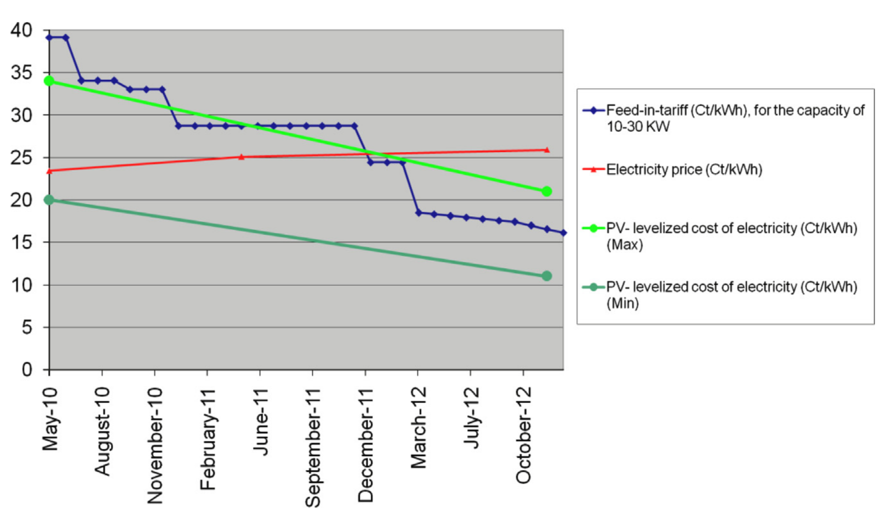

Fig. 1. PV electricity generation costs vs. electricity retail (compiled from [36,37] and Bundesagentur).

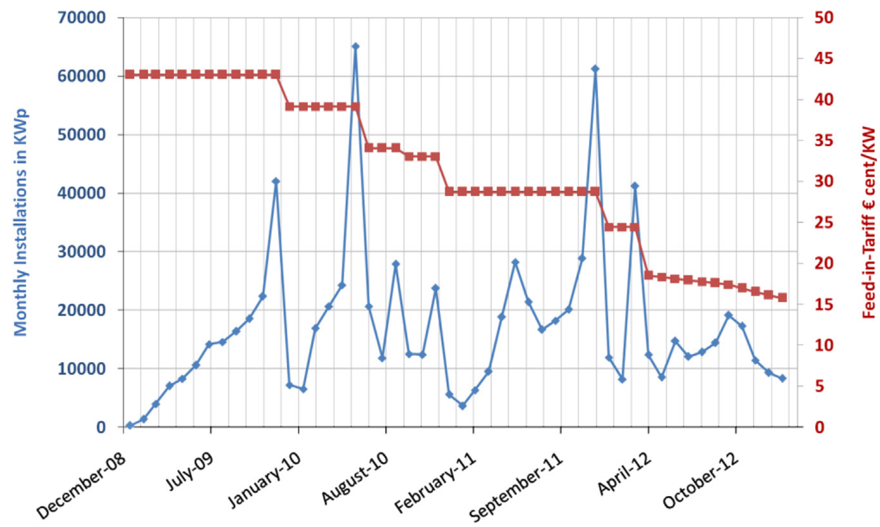

Fig. 2. Monthly installations vs. feed-in tariff in Germany (compiled from Bundesagentur and the Information Platform of four German Transmission Network Operators for the EEG and KWK-G).

increased just before the reductions of the feed in tariff as seen in the months of December 2009, July 2010, December 2010 or July 2011. In contrast, since April 2012, the feed in tariff has diminished gradually month by month, which probably prevents boom and bust cycles but reveals seasonal effects (e.g., high installations between June and October due to favourable weather conditions in the region).

4.2. Hartmann Energietechnik GmbH

Hartmann Energitechnik GmbH (HET) was founded in 1995 in the village of Oberndorf in Rottenburg am Neckar (a town with 43,000 inhabitants) by Thomas Hartmann (he is a local entrepre neur according to the definition of Michelacci and Silva [44]) . HET is located in the so called "Solar Center" and offers solar PV, solar thermal and biomass boilers for the citizens in the neighborhood, in partnership with two regional associations: Solar Partner e.V. and Sonnenhaus Institut e.V. In the PV branch, the main activities of HET are focused on the promotion, consulting, conceptual designing, assembling and installation. HET offers a wide range of solutions, depending on the needs and preferences of potential PV adopters: various montage systems and alternative concepts. In 2012, HET's sales volume was approximately 3 million Euros. In the same year, the PV solutions offered by HET was adopted not only in Rottenburg am Neckar (30% of adoptions) but also in other neighborhoods in a radius of up to 50 km. HET shared an average of 10% of the PV market in the neighboring towns with respect to the installation numbers.

HET history goes back to 1993, when T. Hartmann obtained his first solar collector training for solar thermal systems. In the late 1990s, inspired by an Austrian model, HET installed many different solar systems, participated in different exhibitions and co founded the association Solar Partner e.V, a network of heating and solar specialist companies, freelance solar consultants and partner companies in Bavaria and Baden Württemberg. The installation of the solar thermal for the sport hall in the village of Oberndorf was one of milestones of HET, by which the company achieved visibility and recognition in the neighborhood.

Since the introduction of the feed in tariff for PV in Germany in 2000 by the federal government, HET has focused on the PV systems, installing many systems in the neighborhood (e.g., for the church and the bishop's house in 2002). In the beginning of 2000s, the efforts of HET received attention from the government. In 2001, HET was visited by the Mayor of Rottenburg am Neckar and a member of German parliament, and in 2002, HET was visited by a minister of the regional government to have solar walks and become informed about the diffusion of solar systems in the region.

In 2004, HET co founded the association of Sonnenhaus Institut e.V., an association that brings architects, engineers and managers of the solar industry together with the goal of sustain able development and distribution of construction and heating techniques for largely solar heated buildings. In 2006, as a pilot project of the association, Solar Center was built with PV systems of a capacity of 60 kW_p on the roof and 150 m^2 of solar thermal on the façade that provide 80% of the energy by itself.

HET's relationship with potential adopters is mainly based on the facilities in the "Solar Center" and the monthly "Solar walks". The Solar Center is a place where the potential adopters can see any part of the facilities (assembly hall, design unit, and exhibition part) and become informed about PV solutions. The Solar Center also serves as a meeting place for seminars, construction courses, open doors day and guided tours about solar PV, solar thermal and biomass. In addition, interested potential adopters can request a personal visit by T. Hartmann to their houses to discuss the best option. "Solar walks" are regular 3 4 h exhibition tours in the village of Oberndorf, guided by T. Hartmann, where PV systems that HET installed are described and discussed. Anyone who is interested can join these solar walks and learn about different PV concepts on the field. Since 2001, solar walks have been organized every month, and during this time, it has never failed. The visitors of these solar walks have not been only limited to the region, as there have been many amateur and professional guests from all over the world, e.g. the USA, Japan and Sri Lanka.

5. Results and discussion

The case of HET with PV adopters in the area of Tubingen in 2012 is very appropriate to achieve the purpose of the paper. First, HET is a pioneer local solar company in the region with a strong network with other local solar companies and adopters. Second, the year 2012 is the time when the feed in tariff drastically diminished:

- *"Hartmann Energietechnik GmbH is a local installation company, well known in the region. There are many references in the area,* *and Mr. Hartmann is a very well known guy…" (P.M., PV Adopter, 21.12.2012).*

- *"2012 was catastrophic bad year Solid cut in the feed in tariff." (G.W., Director of a partner firm in HET network, 07.12.2012).*

To understand the motivations to PV adoption in 2012, we separate the analysis into three parts associating with the role of policy measures, local solar companies and adopters (according to the analytical framework presented in Section 2).

5.1. Policy measures

Germany is expected to achieve the National Renewable Energy Action Plan Target for PV for 2020 at an earlier stage than planned, sometime between 2016 and 2020 [19]. This is the impact of the strong policy support that resulted in the rapid growth of the PV market in the 2000s. During this period, the cost covering feed in tariff was the main factor that policy makers implemented to foster market formation and PV diffusion [15]. As expected, this case study reveals that feed in tariff is no longer the most important motivation to adopt PV. This change is a consequence of PV systems achieving grid parity in 2012 and the reduced feed in tariff, which pays less than the average electricity retail price. Although solar PV is supposed to be advantageous compared to other electricity sources due to grid parity, the interviewed managers said that reduction in feed in tariff was the reason why adoption rate of PV in Southern Germany reduced in 2012 in comparison to 2011.[1]

In 2012, the role of policy became more "indirect" than previous years. There is clear evidence in the case study that policy makers, together with other actors, created a negative expectation about the electricity prices in future. This legitimization motivated some households to adopt solar PV systems. Policy measures determine the rules for calculating the EEG levy (the portion of the electricity price that must be paid by the end user to support renewable energy) and other types of taxes, which partly sets the electricity price in the market [61]. In the case study, respondents from both supply and demand side report the importance of the negative future expectations on the adoption decision.

- *"The people in their 30s are afraid of high electricity costs and how to manage it…" (G.W., Director of a partner firm in HET network, 07.12.2012).*
- *"Electricity will be more expensive in the coming years… then I said I just do not want to pay much. I would also have advantages (of it)." (F.Z., PV adopter, 24.01.2013).*
- *"We wanted to invest in PV because of the economical and global situation that we don't know which way we are going." (P.M., PV Adopter, 21.12.2012).*

Policy makers can influence which conceptual design will become the dominant design [62] or disruptive innovation [11] of PV systems. The respondents frequently discussed self consumption, a concept based on an additional battery system and self usage of PV electricity. Whether more people will be motivated to adopt self consumption concept, depends on economic relative advantage of it, which is partially shaped by decreasing feed in tariff and increasing electricity prices:

- *"I believe that the PV (diffusion) will grow even though the policy support and feed in tariff decrease (…). Now we have feed in tariff less than what we pay for electricity, it is 10 cents less… This low feed in tariff means that the self power consumption is becoming increasingly important when people are increasingly afraid and further consider self power consumption…" (G.W., Director of a partner firm in HET network, 07.12.2012).*

Interestingly, corresponding to this tendency, a program to promote small scale storage batteries for photovoltaic systems has started to be subsidized for those that have been installed after 31st December 2012. The official information was released in April 2013. According to this new subsidy program, the concept of self consumption PV systems became more advantageous than any other concept possible [28]. We could also argue that this new subsidy scheme for solar batteries may develop positive externalities by the entry of new firms and the creation of a sub market. In the case study, we observed (e.g., in the 2 day long annual meeting) that the Solar Partner e.V. association collaborated with a new solar battery firm to discuss how to integrate PV systems with battery systems. However, the other functional PV concepts still remain niche markets. Two examples of these niche markets are building integrated photovoltaic systems (a concept in which PV systems are used instead of roofing material) and façade systems (using PV systems on facades):

- *"Building integrated photovoltaic technology is very expensive, very expensive! You can see it only in France because building integrated PV systems are there (in France) subsidized. Building integrated PV architecture is beautiful, no question, much nicer than seal down there, which is set up so artificially. It is just a question of whether the customer can afford it or not." (G.W., Director of a partner firm in HET network, 07.12.2012).*

Regarding the social acceptance of PV systems [32], observations in the case study indicate that policy discussions on renewable energy system is a hot topic in mass media channels. These discussions even reach the young generations through different communication channels. One of the respondent's children reported that the use of renewable energy systems is such an important topic that they comment and discuss such systems in primary schools. Theoretically, this importance is related to two of the perceived attributes of the innovation: compatibility and complexity. Because renewable energy systems are designated as the key tool for the future of the German electricity supply by policy makers, the on going discussions of PV systems decreases PV's perceived complexity and makes them compatible with socio cultural values.

5.2. Adopters

In line with recent literature [1,2], our case study shows that the contribution to an improved natural environment and the ability to gain independence from electricity suppliers are important adopter motivations. In particular, the desire to be independent from electricity suppliers has increased recently because of increasing electricity prices. In addition, respondents indicated that solar PV systems are often perceived as an "investment" alternative to other traditional investment options.

- *"Electricity prices are getting expensive. If you currently have money in the bank, you have interest rate of about 1 percent… With a photovoltaic system you can financially be satisfied…" (B.U., PV adopter, 15.01.2013).*
- *"In the back of my head, I would prefer to be completely self sufficient and if we could (in our current new house) make everything for ourselves and would not need public electricity." (C.W., PV adopter, 29.01.2013).*

[1] In Rottenburg am Neckar the number of PV installations in 2012 was 85% of the installations in 2011.

- *"(My motives were) on the one side to make an investment and on the other side to be environmental friendly, i.e., how I can protect my environment. Then, I thought, yes, I make PV system on it (the roof)." (F.E., PV adopter, 01.02.2013).*

Adopters often recognize the impact of their peers upon the adoption rate of PV at the local, regional, and global levels. At the local level, in line with the literature on peer effects [9,53], the case study confirms that there is a positive influence of previously installed PV systems located nearby on the adoption rate of PV. Peer effects in neighborhoods decrease the perceived complexity for potential adopters and increase the perceived compatibility with the social norms:

- *"Several reasons available (for adopting PV). One reason is that we are living in Tubingen… There are a lot of buildings which have PV systems on the roof…" (P.M., PV adopter, 21.12.2012).*
- *"Since solar systems were actually built more and more, I have been thinking about building a house and equip it with a PV system, (since) 10 years." (H.R., PV adopter, 23.01.2013).*

Finally, corresponding to the regional and global levels, the respondents emphasized that there was an indirect impact of the Fukushima disaster in Japan (2011), followed by the protests against nuclear power in Germany (2011 2012) and the Stuttgart 21 Project (an urban development project in Stuttgart, which was protested based on economic and environmental concerns on 2009 2011). These protests probably had an impact on the decision by the policy makers (on May 2011) to shut down all nuclear reactors by 2022 and on the adoption of the new Act on Granting Priority to Renewable Energy Sources (EEG 2012 on June 2011). This reaction to protests is an interesting illustration that adopters, as change agents, can influence the policy decision and, consequently, the adoption rate of a technology in society.

5.3. Local solar companies

Local solar companies offer and install complete PV systems to adopters and act as change agents, thus making them vital in the adopters' decision process. Corresponding to earlier research [51,8], a mix of all decision types were reported in this case study: "optional decision", in which the location of PV system installation belongs to the adopter; "collective decision", in which multiple adopters live in a common place (e.g., apartment) and have a say in the final decision; and "authority decision", in which the adopter is temporarily occupying the location at which the PV system is installed (e.g., renter). The adoption decision is unlikely to be positive if more than one individual has a say in the decision, e.g. the case of collective decision. However, regardless of the type of decision, local solar companies can offer alternative PV system solutions based on the different needs, which can affect the final decision, e.g., if a potential adopter is building a new house, the local solar company can offer a building integrated PV system to reduce the amount that would have to be spent for conventional building materials because a building integrated PV system is directly used in parts of the building envelope (increase of the relative advantage). Here, offering the best solution that fits the needs of the potential adopter (decreasing complexity and increas ing compatibility) is not only a typical role of an experienced local company but also a key to motivate the adoption.

Respondents of our case study emphasized that the decision to adopt photovoltaic systems requires some level of knowledge about the technology, operation and funding. Many studies, e.g., Dewald and Truffer [14,15], have highlighted the importance of effective communication and the sharing of similar background between suppliers and adopters. This importance of effective communication is related to the variables determining the adoption rate, given the fact that such effective communication minimizes the perceived complexity via change agent efforts, such as a local solar company.

Another finding of our case study is that local solar companies are also important in producing peer effects. Previously, the understanding of peer effects have been limited to the interactions between adopters to adopters in the literature [9]. The case study reveals that local solar companies may also influence the adoption rate via the neighborhood effect on potential adopters due to image motivation. HET has PV systems on its own roof, which is visible from the neighborhood, and offers to open the doors of its solar center to anyone interested through its periodic solar walks and open door days. These interactions improve the trialability of PV systems as perceived by potential adopters.

- *"(…) we are a local company and we have many relative reference systems here in the neighborhood, and yes I think that (the company) is well known. The combination of the brand Thomas Hartmann has built, the solar center and solar walks do talk to the feelings, not just to the purely technical side. There is a building here (the solar center), showing off the products. That is always the most important, if one builds a place where people can see. Not every customer care about the purely technical data, but they want to experience." (S.L., Solar Thermal Expert by HET, 31.01.2013).*
- *"(Why have you chosen HET?) Because I work nearby and I always have contact with HET." (H.J.R., PV adopter, 29.01.2013).*

6. Conclusions

This paper aims to overcome the limitation related to the extant research on the motivators for adoption of PV systems at grid parity. Using an extensive and exploratory case study approach, we analyzed a local case in Southern Germany in respect to the impact of policy measures, adopters and a local solar company. Our findings have demonstrated several important motivators for adoption. Achieving grid parity does not necessarily motivate potential adopters for PV systems. As discussed by Rogers [54], for wide adoption, innovations should not only have high compatibility, high trialability, high observability, high relative advantage and low complexity but also be communicated and driven by change agents, e.g. adopters and other actors.

Most of the adopters in our case have been motivated for PV systems in order to be self sufficient and independent from conventional electricity supply. Such desire is often complemented with environmental awareness, peer effects and financial stability. This is in line with previous research, which investigated similar phenomenon in other countries before grid parity [1,2,32]. In our case, the increasing electricity retail price, as influenced by policy measures, has motivated potential adopters to be less dependent on electricity supply. In this context, PV systems have been often perceived to be compatible with the desire of potential adopters towards being self sufficient and independent.

Moreover, complementary to previous research [15,20], the local solar company is identified to be an important motivator for adoptions. The vision of the company and its local entrepreneur has reduced the perceived complexity of solar PV systems. Several activities organized by the local entrepreneur, e.g., solar walks and open door days, have also increased perceived trialability and the observability of PV systems. Because PV systems require some level of knowledge about the technology and its operation, a high level of communication between local solar companies and adopters is a key factor to minimize the perceived complexity and to facilitate the decision made by the adopters.

Given the multi dimensions of the motivators for diffusion of PV systems at grid parity, there are some limitations to this study, which could motivate to open new avenues for future research. The presented single case study is context limited. However, it provides valuable insights for the knowledge accumulation in a particular research field (see [21]). Therefore, our in depth study may serve as an entry point for investigations in similar contexts. Moreover, during our case study, two topics appeared to be promising for future research. First, the interrelation between recent German policy support for solar batteries and the adoption of PV systems should be studied further. Second, as complementary to the motivators, the future studies could investigate the barriers to the adoption of a variety of PV systems' concepts, among others building integrated systems, at grid parity. In this context, physical availability, lack of coordination between among stakeholders and socio demographic characteristics, as studied in different contexts before grid parity (e.g. see [24,29,35,65]), may serve as a basis for further studies.

As far as practical implications are concerned, we believe that the paper provides insights for policy makers and industrial actors on the motivators for adoption of PV systems in a context characterized by a progressive reduction of the feed in tariff. Given that grid parity does not necessarily fully motivate potential adopters, policymakers might need to consider new policy measures to support local solar companies, which act as important mediators to motivate the diffusion of solar PV systems.

Acknowledgments

We thank the Education, Audiovisual and Culture Executive Agency (EACEA) of the European Commission (Specific Grant Agreement (SGA): 2011 1531) for funding this research within the framework of the European Doctorate in Industrial Management (EDIM), an Erasmus Mundus Action 1 program. We also express our sincere gratitude to Thomas Hartmann (Hartmann Energietechnik GmbH) and his colleagues for giving us the opportunity to learn and to obtain the empirical data. We especially thank Hubert Wellhaeusser, for his great help throughout the case study, and all of the respondents who were interviewed, including the directors from Solar Partner Association and the residents of Rottenburg am Neckar. A shorter version of this paper was presented in the European Forum for Studies of Policies for Research and Innovation (Eu SPRI) Conference 2013 in Spain.

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